(12) UK Patent Application (19) GB (11) 2 313 254 (13) A

(43) Date of A Publication 19.11.1997

(21) Application No 9610315.5

(22) Date of Filing 17.05.1996

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(51) INT CL[6]
H04B 7/005 , H04Q 7/38

(52) UK CL (Edition O)
H4L LDG LDH L1H10

(56) Documents Cited
GB 2295295 A GB 2260242 A EP 0353759 A2

(58) Field of Search
UK CL (Edition O) H4L LDG LDH LDSE LDSJ
INT CL[6] H04B 7/005 , H04Q 7/22 7/32 7/38
On-Line: WPI

(54) Data packet transmission in a cellular radio communication system

(57) The traffic load between a busy cell and adjacent cells with spare capacity is optimized by allocating the transmission of delay unconstrained packet data, such as e-mail, to an adjacent cell. To maintain C/I ratio for the call, the transmitting terminal increases the energy per bit by, for example, reducing modulation rate (ie data rate), using modulation with fewer levels (such as 16 QAM to QPSK), increasing FEC overhead and/or spectrum spreading factor (increased redundancy), or increasing the interleaving depth (spreading interference more widely). As the nominal edge of cell will have been effectively extended, the mobile terminals transmitting data may be closer than normal to a remote cell which is re-using the same frequency. The terminal transmitting data therefore maintains or reduces power to avoid co-channel interference. Reducing power requires the addition of still further reduction in data rate in order to maintain the r quired energy per bit/symbol at the serving base station.

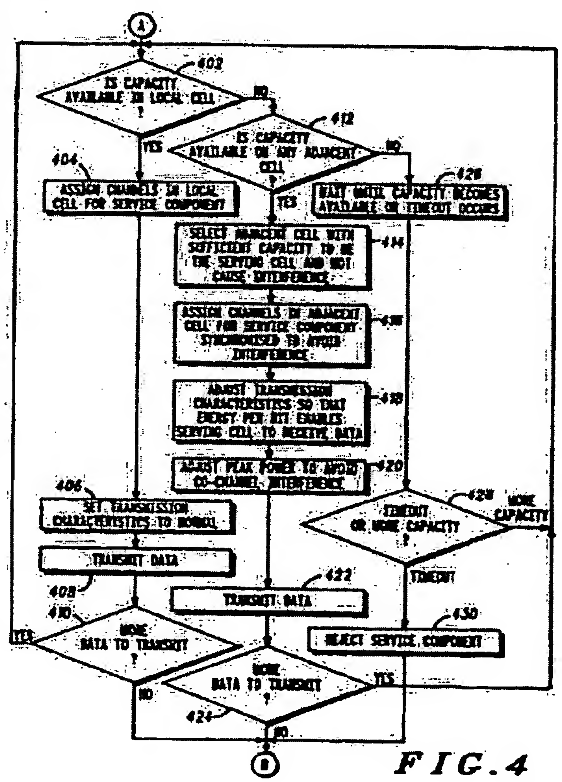

FIG.4

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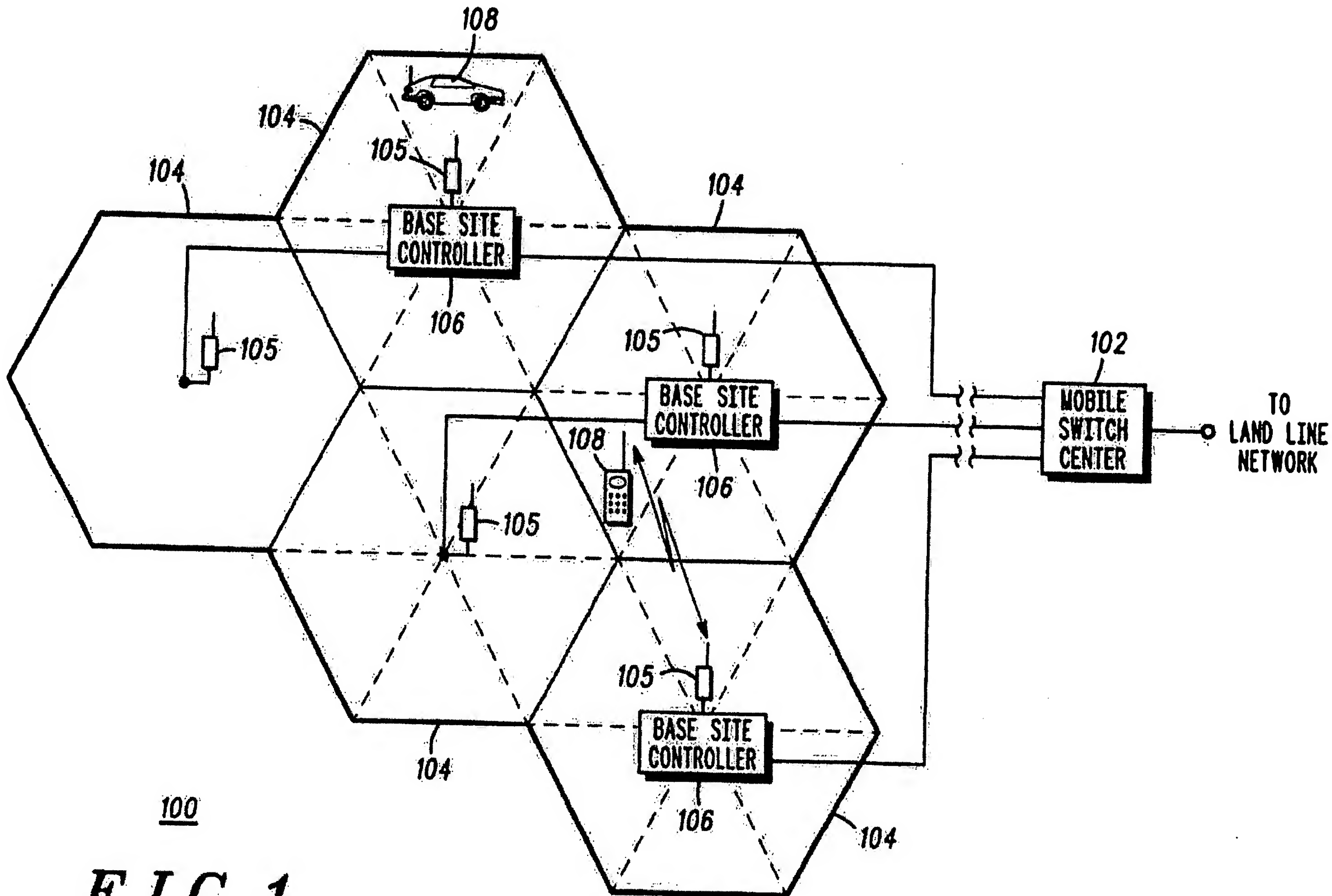
At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.


108
104
105
104
BASE SITE CONTROLLER
104
106
105
105
102
BASE SITE CONTROLLER
MOBILE SWITCH CENTER
TO LAND LINE NETWORK
108
106
105
105
BASE SITE CONTROLLER
104
106
104

100

FIG.1

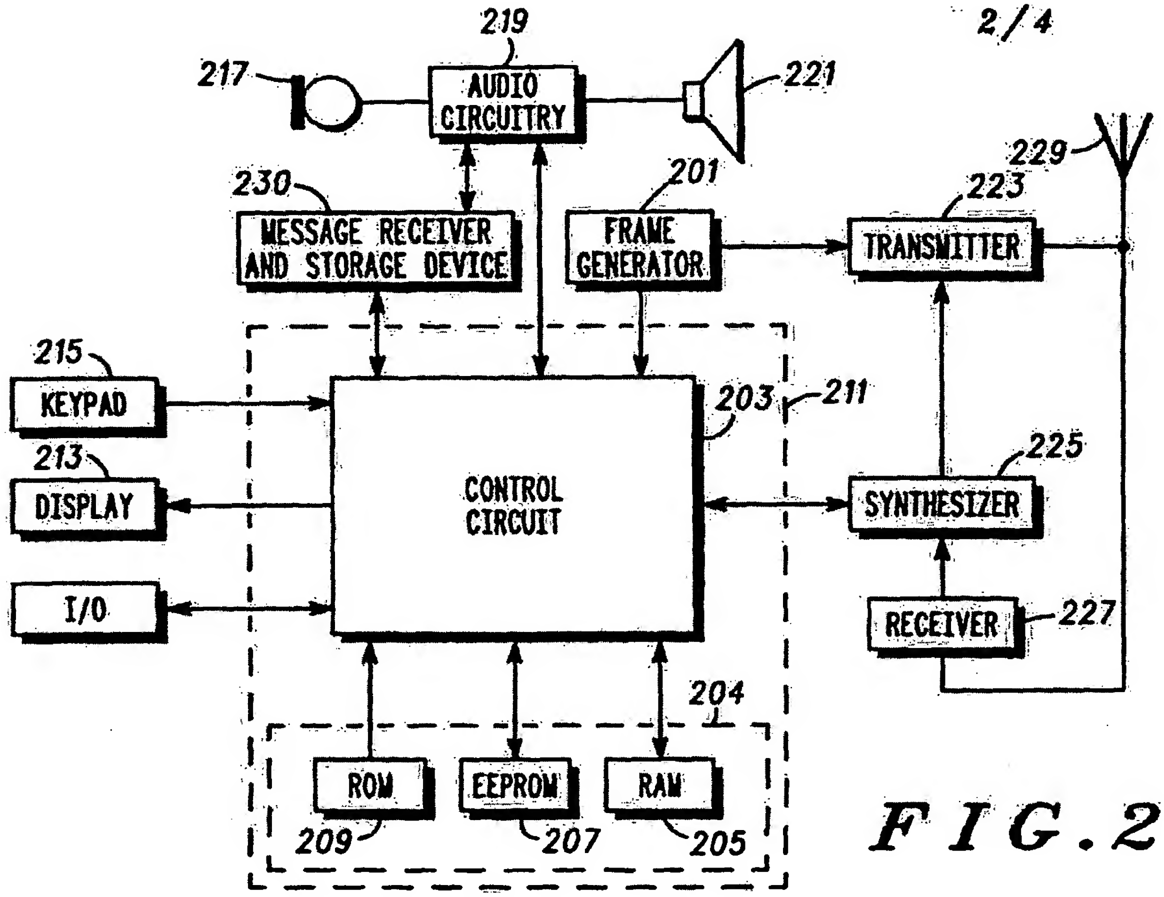

219
217
AUDIO CIRCUITRY
221
229
230
201
223
MESSAGE RECEIVER AND STORAGE DEVICE
FRAME GENERATOR
TRANSMITTER
215
KEYPAD
203
211
225
213
DISPLAY
CONTROL CIRCUIT
SYNTHESIZER
I/O
RECEIVER
227
204
ROM
EEPROM
RAM
209
207
205

FIG. 2

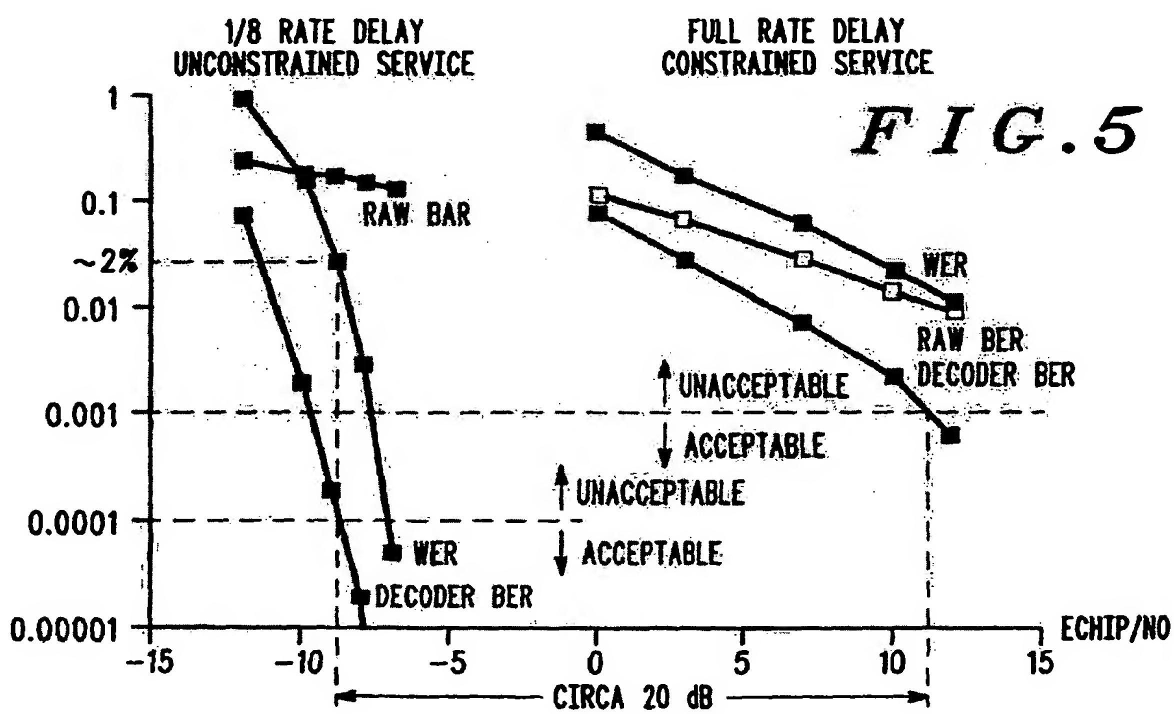

1/8 RATE DELAY UNCONSTRAINED SERVICE
FULL RATE DELAY CONSTRAINED SERVICE
1
0.1
~2%
0.01
0.001
0.0001
0.00001
RAW BAR
WER
RAW BER
DECODER BER
UNACCEPTABLE
ACCEPTABLE
UNACCEPTABLE
ACCEPTABLE
WER
DECODER BER
ECHIP/NO
-15
-10
-5
0
5
10
15
CIRCA 20 dB

FIG. 5

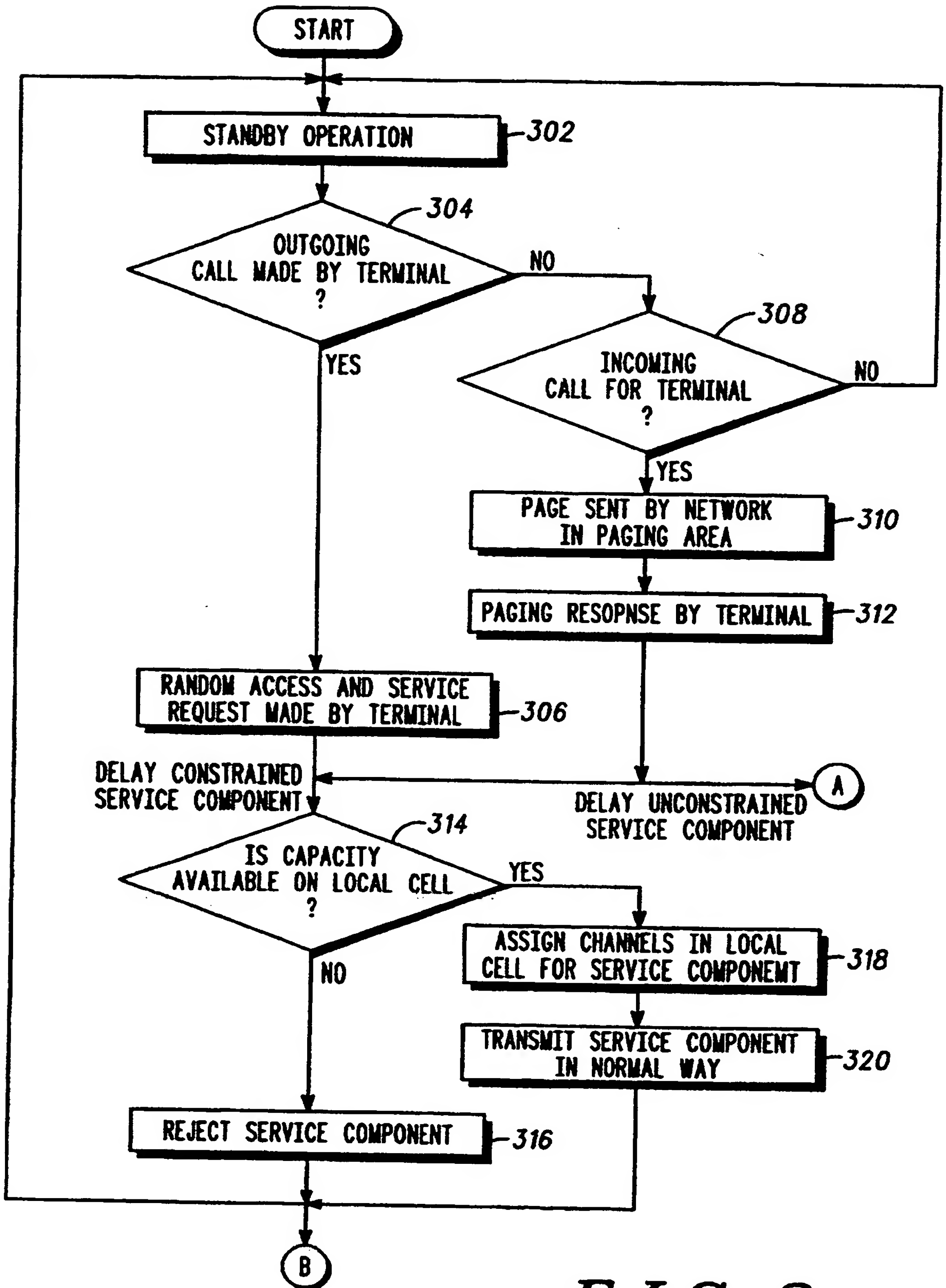

START
STANDBY OPERATION
302
304
OUTGOING CALL MADE BY TERMINAL ?
NO
YES
308
INCOMING CALL FOR TERMINAL ?
NO
YES
PAGE SENT BY NETWORK IN PAGING AREA
310
PAGING RESOPNSE BY TERMINAL
312
RANDOM ACCESS AND SERVICE REQUEST MADE BY TERMINAL
306
DELAY CONSTRAINED SERVICE COMPONENT
DELAY UNCONSTRAINED SERVICE COMPONENT
A
314
IS CAPACITY AVAILABLE ON LOCAL CELL ?
YES
NO
ASSIGN CHANNELS IN LOCAL CELL FOR SERVICE COMPONEMT
318
TRANSMIT SERVICE COMPONENT IN NORMAL WAY
320
REJECT SERVICE COMPONENT
316
B

FIG.3

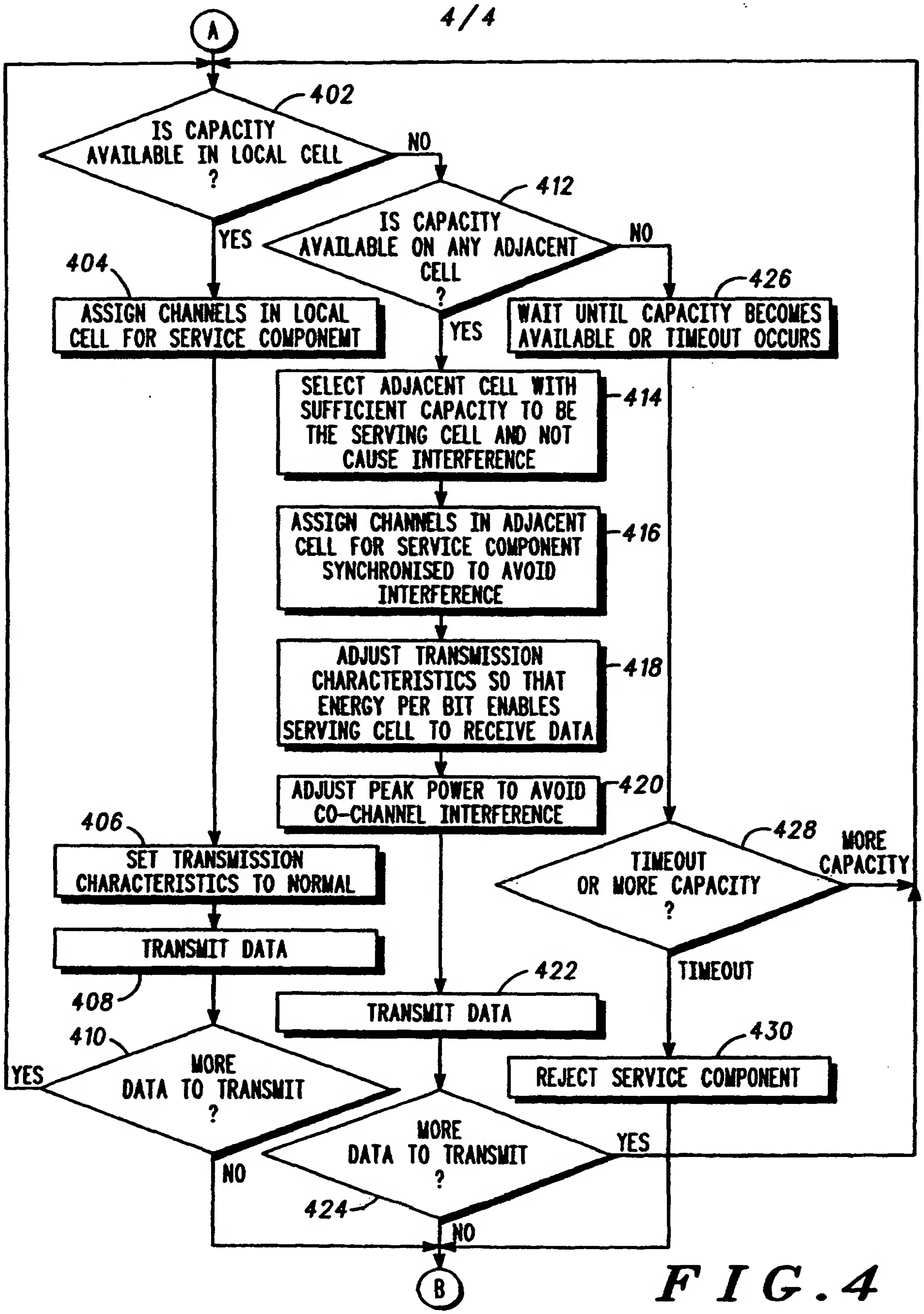

A
402
IS CAPACITY AVAILABLE IN LOCAL CELL ?
NO
YES
412
IS CAPACITY AVAILABLE ON ANY ADJACENT CELL ?
NO
YES
404
ASSIGN CHANNELS IN LOCAL CELL FOR SERVICE COMPONEMT
426
WAIT UNTIL CAPACITY BECOMES AVAILABLE OR TIMEOUT OCCURS
SELECT ADJACENT CELL WITH SUFFICIENT CAPACITY TO BE THE SERVING CELL AND NOT CAUSE INTERFERENCE
414
ASSIGN CHANNELS IN ADJACENT CELL FOR SERVICE COMPONENT SYNCHRONISED TO AVOID INTERFERENCE
416
ADJUST TRANSMISSION CHARACTERISTICS SO THAT ENERGY PER BIT ENABLES SERVING CELL TO RECEIVE DATA
418
ADJUST PEAK POWER TO AVOID CO-CHANNEL INTERFERENCE
420
406
SET TRANSMISSION CHARACTERISTICS TO NORMAL
428
TIMEOUT OR MORE CAPACITY ?
MORE CAPACITY
TIMEOUT
TRANSMIT DATA
408
422
TRANSMIT DATA
410
MORE DATA TO TRANSMIT ?
YES
NO
430
REJECT SERVICE COMPONENT
MORE DATA TO TRANSMIT ?
YES
424
NO
B

FIG.4

2313254

METHOD AND APPARATUS FOR TRANSMITTING DATA

Field of the Invention

The present invention is generally related to communication devices and systems, and more particularly, to a method and apparatus for transmitting data in a wireless communication system.

Background of the Invention

In many wireless communication systems, all of the resources of a cell can be in use at a point in time such that no additional calls can be made. This phenomenon, sometimes known as call blocking, can be very frustrating to the user wishing to make a call. Normally the user has to keep re-dialling until the cell has enough spare capacity to accept the new call. However, when one cell is operating at full capacity, the adjacent cells may have some spare capacity.

In the future mobile public systems will carry a mixture of services, ranging from speech to video, short data, high speed circuit switched data and packet data. This is a much richer mixture of services than is generally found today and any call blocking will be the result of a much more complex mixture of services. Consequently it will be harder to predict and efficiently provide additional capacity for future systems.

In a cellular system, the nominal edge of cell is usually described by the level of interfering energy in the operating frequency. The nominal edge of cell is also strongly influenced by the Forward Error Correction (FEC) techniques such as the interleaving, which has the effect of flattening and spreading out the interference peaks during the call. The nominal edge of cell is normally defined such that it is at the limit of the sensitivity required to maintain all of the services to be supported by the cell, including management and control signalling requirements. The nominal edge of cell is closely associated with the frequency re-use factor, which in turn is closely associated with the spectrum efficiency characteristics of the radio interface. Protocol features, such as FEC, rror d tection, guard tim s, pow r control

are usually configured with the nominal edge of cell characteristics in mind such that satisfactory service performance is achi vable.

Some conventional communications systems use different modulation levels in order to maximise the throughput of data services, depending upon the C/I. Other conventional communications systems use umbrella cells overlaid on top of smaller microcells to increase capacity in a given geographical region at the cost of using more spectrum. Similarly, conventional communication systems use dynamic frequency allocations, where a spare radio frequency is moved from one cell to another in order to add local capacity to a cell that requires this extra capacity. However, this solution requires the additional frequency to be available. More importantly, such a frequency re-use is unlikely to be as efficient as the normal cellular fixed frequency assignments, and many often create difficult system management problems. However, such systems often lead to inefficient use of spectrum. Also, not all services are subject to the same constraints.

Accordingly, there is a need for a method and apparatus for transmitting data efficiently in a wireless communication system.

There is also a need for a method and apparatus for transmitting data in an adjacent cell in a wireless communication system.

There is a further need for a method and apparatus for transmitting both delay constrained and delay unconstrained data efficiently in a wireless communication system.

Brief Description of the Drawings

FIG. 1 is a plan view of a wireless communication system according to the present invention;

FIG. 2 is a block diagram of a mobile terminal according to the present invention;

FIG. 3 is a flow chart showing the call set-up procedure according to the present invention;

FIG. 4 is a flow chart showing the method for transmitting data according to the present invention; and

FIG. 5 is chart showing error information for data transmitted according to the present invention.

Detailed Description of the Invention

The present invention provides a method and apparatus for exploiting the fundamentally different natures of packet switched and circuit switched services in order to balance the traffic load between a busy cell and nearby cells which have some spare capacity and operate on a different frequency than the busy cell. The invention can be employed almost instantaneously as the load changes from cell to cell and requires no additional frequencies.

One of the unique characteristics of mobile packet data services, both connectionless and connection oriented, is that the services are tolerant to an unpredictable end to end delay. By accommodating this unpredictable delay, it is possible to meet or exceed a guaranteed quality threshold and allow for routing changes within the system. Many applications for packet data ,such as email, are extremely flexible and can accommodate extremely long and unpredictable end to end delays. Most other mobile telecommunications services, such as voice, video and circuit switched data, require a virtually fixed delay, but can tolerate variable bit error rates to some extent. Removal of certain service constraints gives extra degrees of freedom when designing protocols, which in turn can be used to increase the overall capacity of the system with no additional hardware costs.

The present invention finds particular application where a busy cell is carrying a mixture of services which include a proportion of packet data services, and an adjacent cell on a different frequency has some spare capacity. In essence the nominal edge of cell for the adjacent cells with spare capacity is extended for packet data services. This extension is achieved by targeting the specific instances of packet data services which can accommodate an increase in delay, and deliberately slowing down the throughput of these targeted packet data services in order to allow the specific targeted packet data services to be transferred to the adjacent cell. By transmitting packet data on an adjacent cell, the communication system can maximise the capacity of the system, and avoid denying a request for service for which a local cell would not have the capacity.

Turning now to FIG. 1, a wireless communication system 100 is shown. Wireless communication system 100 preferably includes a mobile switching centre 102, a plurality of cell sites 104 each having a base station 105 coupled to base site controllers 106. Each base station provides radio frequency (RF) cov rage to a geographical region. Finally, mobil communication devices 108

or portable communications devices 110 (collectively "mobile terminals") are adapt d to communicat with base stations associated with base site controll rs 106 to maintain communications with another mobile terminal or a wireless unit associated with a landline system. Each base station is assigned a predetermined set of channels according to a frequency reuse pattern which is well known in the art of cellular communication. The channels in each cell are generally divided into control channels which generally enable call set up, and traffic channels for transmitting voice or data traffic. The allocation and use of channels varies between communication systems, but are well known in the art.

Turning now to FIG. 2, a block diagram shows a mobile terminal such as a cellular radiotelephone or other wireless communication device according to the present invention. In the preferred embodiment, an ASIC (Application Specific Integrated Circuit) 201, such as a CMOS ASIC available from Motorola, Inc. and microprocessor 203, such as a 68HC11 microprocessor also available from Motorola, Inc., combine to generate the necessary communication protocol for operating in the communication system. The microprocessor 203 uses RAM 205, EEPROM 207, and ROM 209, consolidated in one package 211 in the preferred embodiment, to execute the steps necessary to generate the protocol and to perform other functions for the terminal, such as writing to a display 213, accepting information from a keypad 215, and controlling a frequency synthesizer 225. The ASIC 201 processes audio transformed by the audio circuitry 219 from a microphone 217 and to a speaker 221. Transmitter 223 transmits through an antenna 229 using carrier frequencies produced by the frequency synthesizer 225. Information received by the communication unit's antenna 229 enters the receiver 227 which demodulates the symbols comprising the message frame using the carrier frequencies from the frequency synthesizer 225. The wireless communication device may optionally include a message receiver and storage device including digital signal processing means. The message receiver and storage device could be, for example, a digital answering machine or a paging receiver. While the circuitry of FIG. 2 shows an exemplary terminal, other circuitry could be employed within the scope of the present invention.

Turning now to FIG. 3, the preferred steps for setting up a call are shown. In a step 302, the terminal is in standby operation. The terminal then determines in a step 304 whether an outgoing call is made. If an outgoing call is made, random access and a s rvice request is made by the terminal at a step

306 according to the system specification. If no outgoing call is made at step 304, the terminal determines whether an incoming call is detected at a step 308. If no incoming call is detected, the terminal continues standby operation at step 302. However, if an incoming call is detected, a page is sent by the system in the paging area at a step 310. Preferably, the paging area may include multiple cells as is well known in the art to increase spectrum efficiency. The terminal sends a paging response at a step 312 to receive the call.

The system then determines whether components of the service are delay constrained or delay unconstrained. Accordingly, the present invention finds particular applicability for a terminal adapted to simultaneously transmit delay constrained and delay unconstrained data, such as voice and data. If a component of the service is delay constrained, such as voice, video or high speed current switched data, the system determines whether there is capacity available on the local cell at a step 314. If there is no capacity the system rejects the delay constrained service component at a step 316. If there is capacity available, the system then assigns traffic channels in the local cell to the terminal for the delay constrained service at a step 318. The delay constrained traffic is then transmitted in the normal fashion at a step 320.

Turning now to FIG. 4, the preferred steps for transmitting delay unconstrained data, such as mobile packet data, on an adjacent cell according to the present invention are shown. The delay unconstrained data could be transmitted alone, or simultaneously with any delay constrained data transmitted on frequencies in the local cell as described above. At a step 402, the network determines whether there is capacity available in the local cell. If there is capacity available, the system assigns channels in the local cell for the delay unconstrained service component at a step 404. The terminal then sets the transmission characteristics to normal at a step 406 and transfers the data at a step 408 according to conventional methods. If there is more data to transmit at a step 410, the system determines whether capacity is available on the local cell at step 402. If there is no more data to transmit, the terminal returns to standby operation at step 302 of FIG. 3.

If there is no capacity available on the local cell at step 402, the system determines whether there is capacity available on any adjacent cell at step 412 by monitoring activity on channels of the adjacent cells for a predetermined period of time. If there is capacity available, the system selects an adjacent cell of sufficient capacity to be th serving cell and not caus interference in th

system at a step 414. The system then assigns channels in th adjacent cell for the d lay unconstrained data synchronised to avoid interference at a st p 416. The terminal or the base station in the adjacent cell then adjusts transmission characteristics so that the energy per bit enables the other terminal or base station to receive data at a step 418.

Although there are a number of means of slowing down the targeted packet data services, the preferred method is to increase the energy per bit or symbol while not increasing the peak power. Some exemplary techniques of achieving this include reducing the modulation rate (i.e. symbol rate), moving to a modulation with fewer levels (e.g. 16 QAM to QPSK), increasing the FEC overhead and/or spread spectrum spreading factor (i.e. more redundancy), or increasing the interleaving depth (i.e. spreading the interference more widely). One or more of the above specific techniques can be applied in combination with a change in frequency to the frequency of the adjacent cell. However, it is important not to increase the peak power, since the peak power will determine the level of interference into another cell where the same frequency is being re-used.

As the nominal edge of cell will have been effectively extended for the packet data services, it is likely that some of the terminals transmitting data according to the present invention will be closer than normal to a remote cell which is re-using the same frequency. Accordingly, the terminal also adjusts power to avoid co-channel interference at a step 420 to transmit data at a step 422. The peak power of the terminal when transmitting must in fact be lowered in proportion to the interference generated at that remote cell. This requires the addition of still further delay to the delay unconstrained service in order to maintain the required energy per bit/symbol at the serving base station. However, since the service will have been specifically targeted as being able to accommodate the longer delays, such a further delay should not cause a problem for the user. Note that this reduction in peak power is related to the well known "near-far" effect and is only applicable to transmissions from the terminal, not the base station. Notably, the relative reduction in separation distance can be minimised and controlled by only allowing the packet data service to be transferred to an adjacent cell where there is a 7 cell re-use pattern or greater. Any reduction may not be necessary if the frequency is in fact not re-used nearby.

Additionally, if th reduction in th separation distance still has the capability to cause int rference in the cell which is re-u ing the frequency, even after the reduction in transmit power has been taken into account, the following further mitigation technique may be applicable. If the adjacent cell experiencing interference("the victim cell") is also lightly loaded, it will be possible to schedule the transmissions of the interfering mobile such that it only transmits during periods of time when there are no active mobile being served by the victim base station, thus isolating any remaining potential interference in the time domain. When the packet data service has been transferred to an adjacent cell, the mobility management of the system may have to distinguish the user's location in terms of service type. For example, incoming data packets will be routed to a different cell than incoming speech calls.

In a further aspect of the invention, in order to provide efficient means of indicating incoming traffic, and indeed as a further means of load balancing, the paging and access channels for all services may reside on the adjacent cells. This would enable a handset to monitor only one paging channel, and would relieve signalling burden from congested cells.

The terminal then determines whether there is more data to transfer in a step 424. If there is more data to transfer, the system determines whether there is capacity available on the local cell at step 402. Otherwise, the terminal returns to standby mode.

If there is no capacity available on the adjacent cell at step 412, the system waits until capacity becomes available or a time out occurs at a step 426. If more capacity becomes available at a step 428, the terminal determines whether the capacity is available on the local cell at step 402. If a time out expires before capacity becomes available, the system rejects the service component at a step 430 and returns to standby mode.

Turning now to FIG. 5, a chart shows the error rate (expressed as a bit error rate (BER) or word error rate (WER)) in a system transmitting both delay constrained and delay unconstrained data. Delay constrained services are generally concerned with BER , while packet data is generally concerned with WER. As can be seen from the chart, the acceptable threshold for error in full data rate delay constrained service, such as voice, is higher than for the rate in delay unconstrained service, such as e-mail. The energy per bit noise may be